3.5.4. AERMET Processing Options

EPA released AERMET Version 12345 which included a beta option, ADJ_U*, to better account for turbulence in the atmosphere during low wind speed stable conditions. Subsequent releases of AERMET have incorporated modifications to the ADJ_U* formulation to better address micrometeorological refinements (e.g. Bulk Richardson Number, low solar elevation angles). The ADJ_U* option adjusts the surface friction velocity parameter (U*) used by AERMET in certain low wind speed situations. This option, based on a peer-reviewed study[12], was added to AERMET by EPA to address the tendency of AERMET/AERMOD to underestimate dispersion and thus overestimate ground-level pollutant concentrations for low-level sources under low wind speed conditions, especially for shorter-term averaging periods. Given the refined nature of this beta option and the peer reviewed studies which have acknowledged its accuracy, including EPA, FutureFuel has incorporated this AERMET option. A detailed justification for the use of ADJ_U* is contained in Appendix A.

The AERMET data processing procedure utilized regulatory default options in this case[13,14] with the exception of the ADJ_U* option. The options selected include:

- MODIFY keyword for upper air data
- THRESH_1MIN 0.5 keyword to provide a lower bound of 0.5 m/s for 1-minute wind data
- AUDIT keywords to provide additional QA/QC and diagnostic information
- ASOS1MIN keyword to incorporate 1-minute wind data
- NWS_HGT WIND 10 keyword to designate the anemometer height as 10 meters
- METHOD WIND_DIR RANDOM keyword to correct for any wind direction rounding in the raw ISHD data
- METHOD REFLEVEL SUBNWS keyword to allow use of airport surface station data
- Default substitution options for cloud cover and temperature data were not overridden
- Default ASOS_ADJ option for correction of truncated wind speeds was not overridden
- ADJ_U* beta option was used

3.6. MODELED RECEPTORS

A comprehensive Cartesian receptor grid extending out to approximately 20 kilometers from FutureFuel and Entergy will be used in the AERMOD modeling analysis to assess maximum ground level 1-hour SO_2 concentrations. The Modeling TAD states that the receptor grid must be sufficient to determine ambient air quality in the vicinity of the source being studied. Preliminary modeling analyses were conducted to determine appropriate extents for the modeled receptor grids, which will consist of the following:

- 50-meter spacing along both the facilities fencelines (fenceline grids);
- 100-meter spacing extending from the Entergy fenceline to 5 kilometers (Entergy fine grid);
- 100-meter spacing extending from the FutureFuel fenceline to 7 kilometers (FutureFuel fine grid);
- 200-meter spacing extending from 7 to 10 kilometers around FutureFuel (FutureFuel medium grid); and
- 500-meter spacing extending from 10 to 20 kilometers around FutureFuel (FutureFuel coarse grid); and

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[12] Qian and Venkatram. 2011. "Performance of Steady-State Dispersion Models Under Low Wind-Speed Conditions." *Boundary-Layer Meteorology*, Volume 138, Issue 3, pp 475-491.

[13] Fox, Tyler, U.S. Environmental Protection Agency. 2013. "Use of ASOS Meteorological Data in AERMOD Dispersion Modeling." Available Online: http://www.epa.gov/ttn/scram/guidance/clarification/20130308_Met_Data_Clarification.pdf

[14] U.S. Environmental Protection Agency. 2014. "User's Guide for the AERMOD Meteorological Preprocessor (AERMET)". EPA-454/B-03-002, November 2004).

- 1,000-meter spacing extending out 20 kilometers around both facilities (Overall coarse grid).

The above receptor data will be used without modification in the modeling. Per the Modeling TAD, a number of receptors located over the White River could be excluded from the modeling domain because ambient monitors could not reasonably be placed at these locations, but these receptors will be retained in this analysis as a measure of conservatism.

The AERMOD model is capable of handling both simple and complex terrain. Through the use of the AERMOD terrain preprocessor (AERMAP), AERMOD incorporates not only the receptor heights, but also an effective height (hill height scale) that represents the significant terrain features surrounding a given receptor that could lead to plume recirculation and other terrain interaction.[15] Receptor terrain elevations input to the model will be interpolated from National Elevation Database (NED) data obtained from the USGS. NED data consist of arrays of regularly spaced elevations. The array elevations will be at a resolution of 1 arc second (approximately 30 m intervals) and will be interpolated using the latest version of AERMAP (version 11103) to determine elevations at the defined receptor intervals. The receptor grids that will be modeled are shown in Figure 3-4.

[15] US EPA. *Users Guide for the AERMOD Terrain Preprocessor (AERMAP)*, EPA-454/B-03-003, Research Triangle Park, NC.

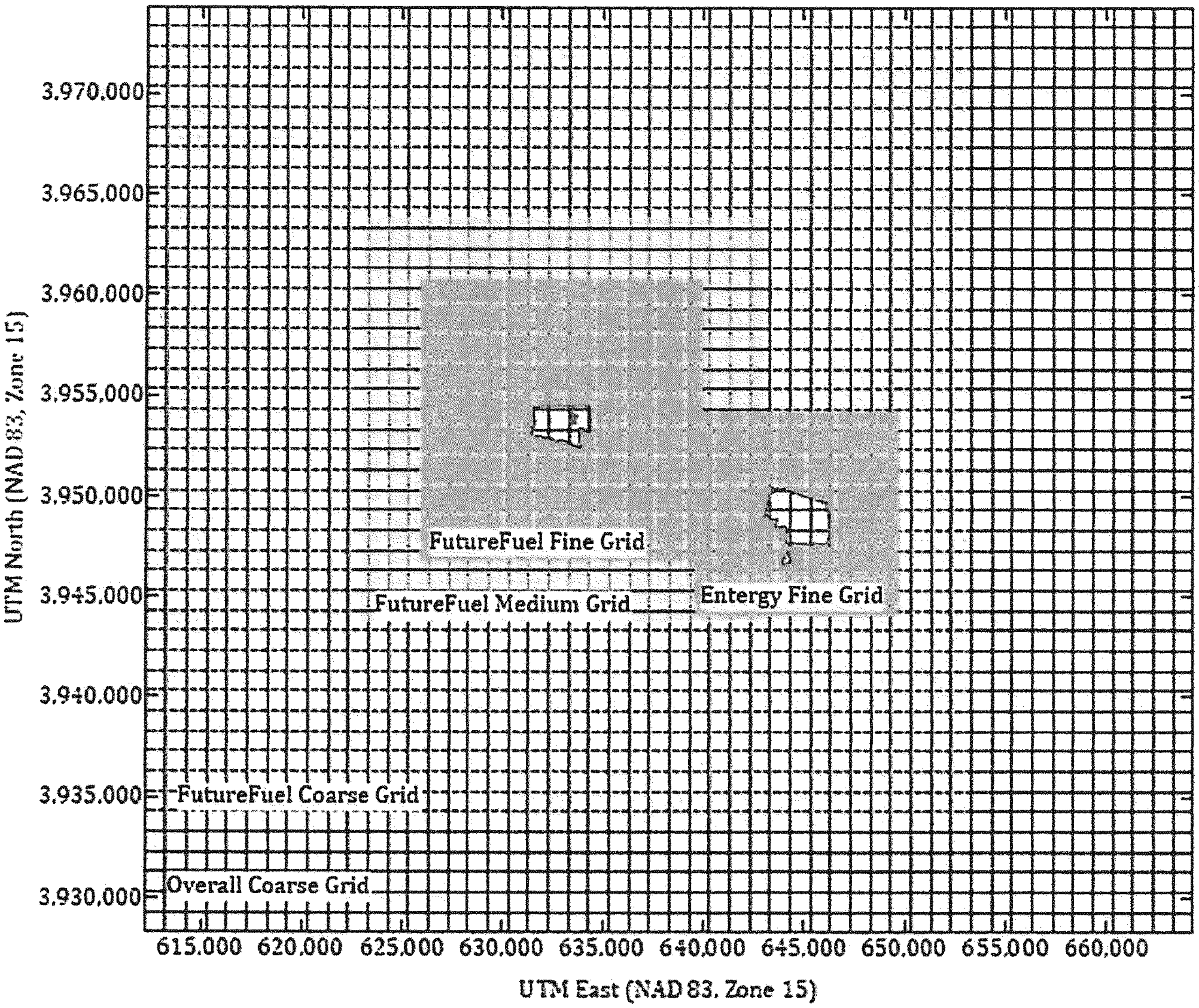

Figure 3-4. Receptor Grids

3.7. BUILDING DOWNWASH

AERMOD incorporates the Plume Rise Model Enhancements (PRIME) downwash algorithms. Direction specific building parameters required by AERMOD are calculated using the BPIP-PRIME preprocessor (version 04274). Downwash effects will be considered through the use of this program.

EPA has promulgated stack height regulations that restrict the use of stack heights in excess of "Good Engineering Practice" (GEP) in air dispersion modeling analyses. Under these regulations, that portion of a stack in excess of the GEP height is generally not creditable when modeling to determine source impacts. This essentially prevents the use of excessively tall stacks to reduce ground-level pollutant concentrations. However, since the DRR modeling process is determining attainment for the area around a facility, the TAD document appropriately recommends that actual stack heights be used.

APPENDIX A: USE OF ADJ_U* IN FUTUREFUEL SO_2 DISPERSION MODELING

When AERMOD is run with a meteorological dataset derived from one-minute meteorological data as is currently recommended by U.S. EPA, low wind speeds are much more prevalent than in prior versions of the modeling system that did not rely on one-minute meteorological data. These low wind speeds have been linked to potential overestimates in ambient concentrations by AERMOD.[16] These overestimates occur, in part, due to an underestimate of friction velocity (u*) by the AERMET meteorological processor. U.S. EPA recognized this underestimation as a potential issue with AERMET and released AERMET Version 12345 which included a beta option, ADJ_U*. The ADJ_U* beta option allows the friction velocity (u*) to be adjusted using the methods of Qian and Venkatram[17] to better account for turbulence in the atmosphere during low wind speed stable conditions. This beta option was updated to incorporate a modified Bulk Richardson Number methodology in version 13350, was further modified to adjust u* for low solar elevation angles with version 14134, and was most recently used to modify the calculation of the turbulence measure, Monin-Obukhov length in Version 15181.[18] Given the refined nature of this beta option and the peer reviewed studies which have acknowledged its accuracy, FutureFuel is proposing to incorporate this option into the modeling analysis to allow more representative and more accurate modeling results.

The U.S. EPA has proposed to make the ADJ_U* option a regulatory default in the forthcoming revisions to the *Guideline*.[19] Currently, however, the u* option is not a default option in AERMOD, the combined use of AERMOD plus the u* adjustment in the meteorology file (generated by AERMET) would no longer have "preferred" status in the sense that it is a model to be used for regulatory purposes without additional regulatory authority approval. To substantiate that the adjusted friction velocity option in AERMOD is a valid model to use in this situation, Section 3.2 of Appendix W describes steps to be considered to allow the use of the u* adjusted AERMOD as an acceptable alternative model. The section also describes criteria for determining the acceptability of an alternative model. Section 3.2.2.b states that satisfying any one of the three alternative conditions may make use of an alternative model acceptable. Condition 1 states that the alternative model will demonstrate equivalency. But in this case the AERMOD Model is the preferred model of choice with just an option change (making it alternative). Because the model cannot have a demonstration of equivalency to itself and the option change will result in different results, this condition is not applicable. This leaves the satisfaction of Conditions 2 and 3 as criteria to accept the u* option in AERMOD. Condition 2 requires the formal submittal of a protocol to allow demonstration of superior performance which is acceptable to the control agency and to FutureFuel. This type of study would require appropriate ambient air quality monitoring and side-by-side modeling and comparisons which are well beyond the scope of this modeling demonstration.

Thus, Condition 3 was reviewed and followed along with the individual criteria to meet its requirements. Section 3.2.2.e states that an alternative refined model may be used provided that five criteria are met. These are:

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16 *Wenjun Qian and Akula Venkatram, "Performance of Steady State Dispersion Models Under Low Wind-Speed Conditions," Boundary-Layer Meteorology, no. 138 (2011): 475-491.*

17 Ibid.

18 http://www.epa.gov/ttn/scram/7thconf/aermod/aermet_mcb3.txt; http://www.epa.gov/ttn/scram/7thconf/aermod/aermet_mcb4.txt; http://www.epa.gov/ttn/scram/7thconf/aermod/AERMET_mcb5.pdf; http://www.epa.gov/ttn/scram/7thconf/aermod/AERMET_mcb6.pdf

19 https://www3.epa.gov/ttn/scram/11thmodconf/9930-11-OAR_AppendixW_Proposal.pdf

i. The model has received a scientific peer review;
ii. The model can be demonstrated to be applicable to the problem on a theoretical basis;
iii. The data bases which are necessary to perform the analysis are available and adequate;
iv. Appropriate performance evaluations of the model have shown that the model is not biased towards underestimates; and
v. A protocol on methods and procedures to be followed has been established.

Review of these criteria as well as the responses to each within the context of modeling for FutureFuel have shown the use of the u* option, as generated by AERMET in the meteorological file and used in AERMOD, to be valid and representative for the modeling domain in the vicinity of the facility. The response to each criteria is given in the following Appendix A subsections.

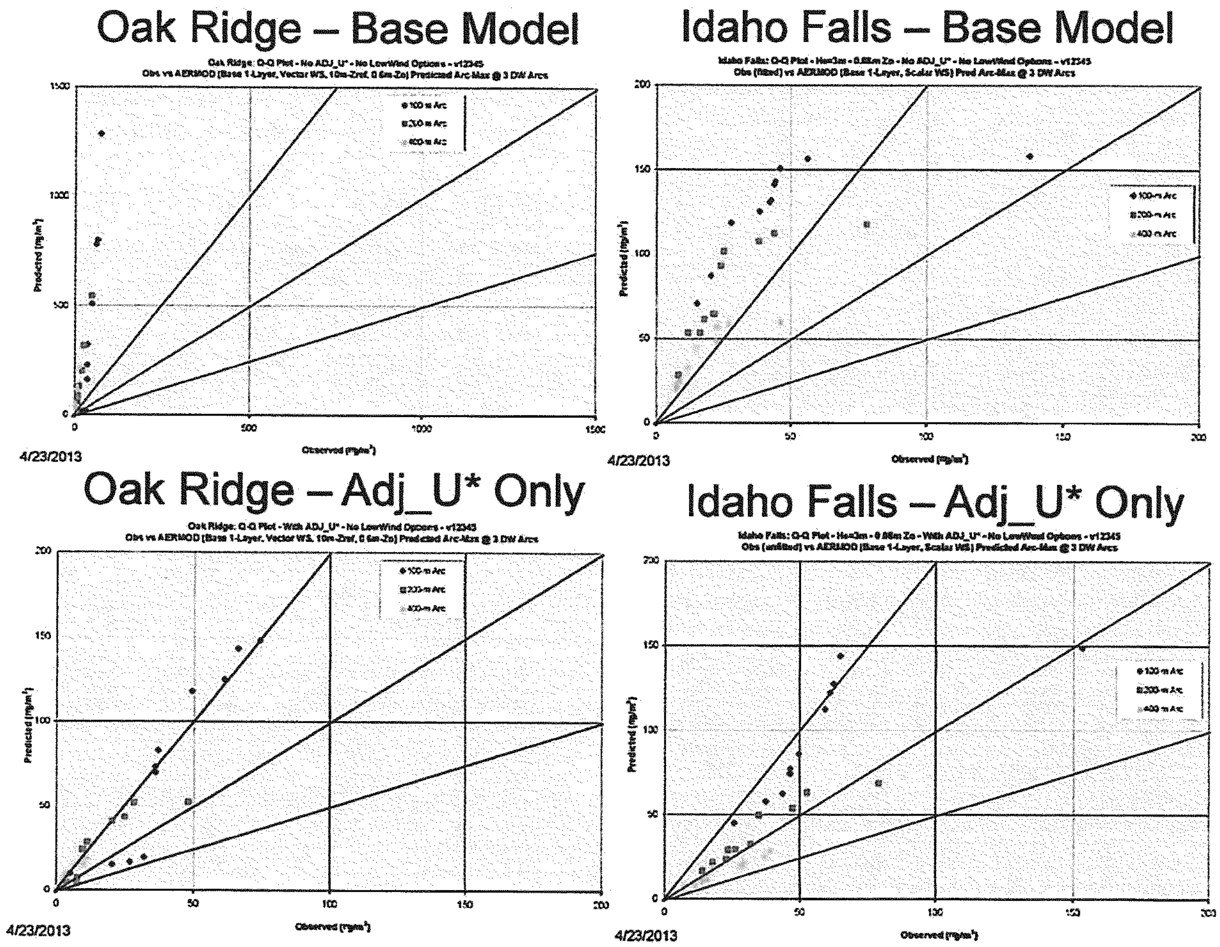
CRITERIA 3.2.2.e.i - SCIENTIFIC PEER REVIEW

The use of an adjusted friction velocity in AERMOD has received scientific peer review and been evaluated both by U.S. EPA modelers as well as others in the scientific and modeling community. Three examples are:

- The paper entitled "Performance of Steady-State Dispersion Models Under Low Wind-Speed Conditions" by Wenjun Qian and Akula Venkatram, Boundary Layer Meteorology, Volume 138, pp 475-491, 2011. This paper examined the AERMOD Model to estimate dispersion under low wind speed events. Two tracer studies, the Prairie Grass Experiment and the Idaho Falls experiment, were compared to the use of AERMOD with and without u* adjustments. The analysis reports that the tendency of AERMOD to overestimate ambient air impacts during low wind speed events was reduced by incorporating an empirical modification. This modification is incorporated into the AERMET program through the ADJ_U* keyword. This option generates the enhanced friction velocity datasets on a low wind speed, stable atmosphere, hour-by-hour basis. Also in his email memorandum dated June 26, 2013, George Bridgers of the U.S. EPA's Office of Air Quality Planning and Standards, notes that "The AERMET BETA option is based on a peer reviewed study (Qian and Venkatram, 2011) which also includes independent evaluations of the new u-star estimates...".
- In his April 23, 2013 presentation at the Regional/State/Local Modeling Meeting in Dallas, Texas, Roger Brode showed "improved AERMOD performance" when including the u* adjustment. The figures below from Mr. Brode's presentation demonstrate the enhanced performance of AERMOD for two field data bases, namely the Oak Ridge Study and the Idaho Falls Study. The closer the points are to the center line of each graph, the better the model performance.

ED_001313_00004179 EPA008762_0000283

Figure A-1. Comparison of the AERMOD Model with and without the u* Adjustment



- The paper entitled "Evaluation of low wind modeling approaches for two tall-stack databases" by Robert Paine, Olga Samani, Mary Kaplan, Eladio Knipping and Naresh Kumar, Journal of the Air & Waste Management Association, 65:11, 1341-1353. This paper evaluates model performance for the LOWWIND options in AERMET and AERMOD for two databases: Mercer County, North Dakota and Gibson Power Station in Indiana. Since the Indiana database is in an area with flat terrain, it is not applicable to this modeling analysis. However, the North Dakota databases consists of tall stacks in rolling terrain, including monitor locations at elevations above stack base elevation, which is similar to the terrain surrounding the FutureFuel Chemical site. As shown in Table 4 of the paper, the predicted/observed impact ratios where improved from 2.20 to 1.53 for the monitor location (DGC #17) in the elevated terrain surrounding the sources.

CRITERIA 3.2.2.e.ii - APPLICABLE ON A THEORETICAL BASIS

Over the past several years many scientific studies have noted that Gaussian dispersion models tend to over predict concentrations at low wind speeds. In the early days of dispersion modeling when the threshold velocities of the National Weather Service anemometers were a few miles per hour, the common use of 1 m/s as the lowest wind speed that would be considered in the model was prevalent. The modeling community recognized that winds lower than that would result in ambient concentration estimates that were not coincidental with ambient monitored values at these same low wind speed conditions. Because concentration is inversely proportional to wind speed, impacts increase greatly as wind speeds fall below 1 m/s. In addition, other studies and field research showed that winds tend to meander during low wind speeds, meaning that the wind was not in only one direction during the time step of the Gaussian models, namely one hour, but tended to change over the time step. The relationship between this phenomenon and the friction velocity calculations in AERMET determined that adjusting the u* could have the same effect as adjusting plume meander and was better estimated empirically (as demonstrated in the peer reviewed paper by Qian and Venkatram).

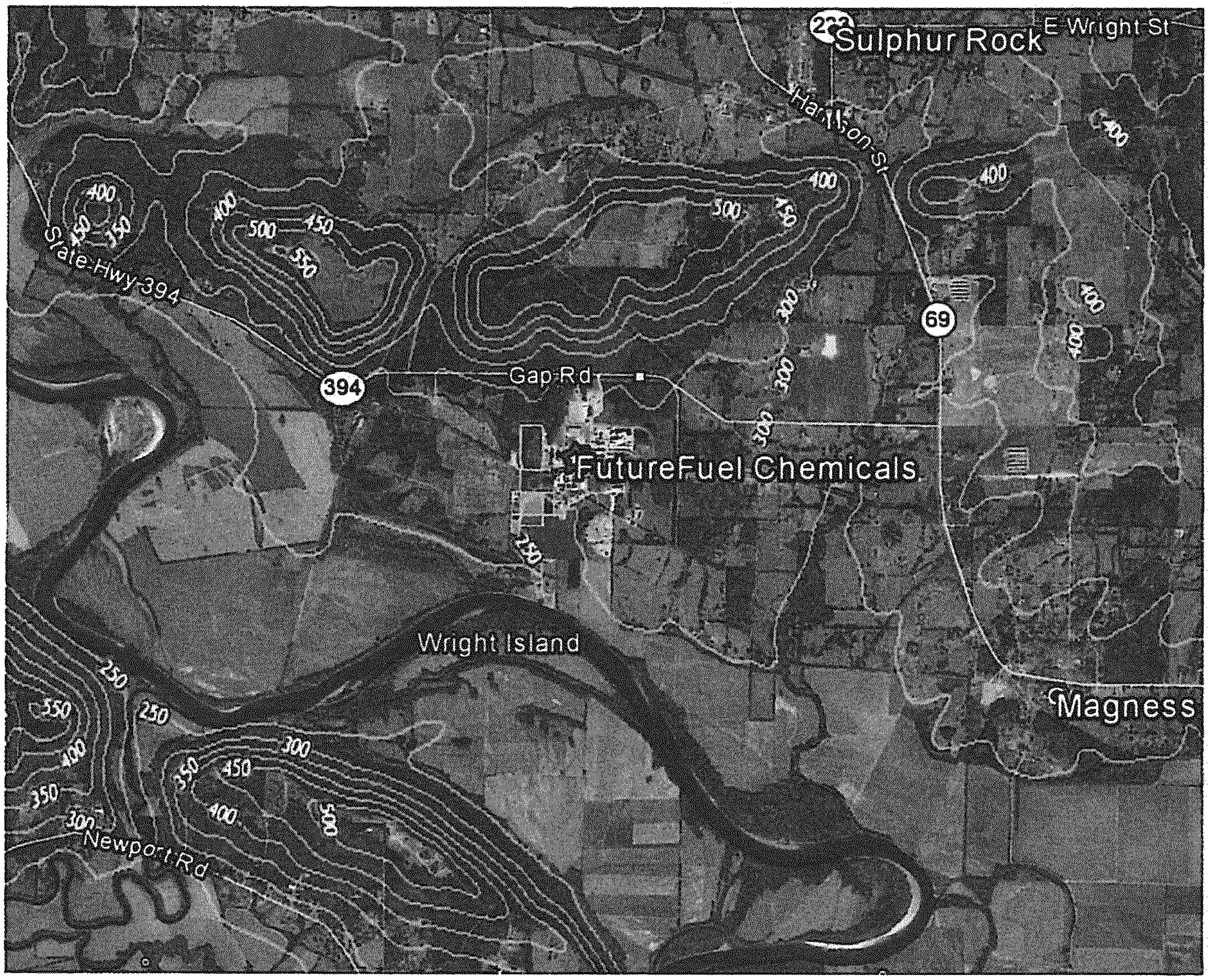
In reviewing the frequency distribution of winds from the Little Rock, AR Airport for the period of record of this modeling analysis, the number of hours in the range of 0.28 m/s (the lower limit where AERMOD will make a calculation) and 3.1 m/s wind speed is 12,414 hours over the three year period of record or 47.2%. In fact, the observed wind speeds are less than 2 m/s for 6,327 hours (24.1%) over the 2012-2014 modeling period. The overall distribution is shown in Table A-1. As previously discussed, the incorporation of the 1 minute ASOS wind observations has greatly reduced the number of calm (and thus unmodeled) hours and replaced them in many cases with low wind speed hours. Thus, the consideration of better science in terms of the u* adjustment is applicable and reasonable given this relatively high frequency of low wind occurrences.

Table A-1. Distribution of Hourly Observations by Wind Speed and Wind Direction

Dir\Spd	<= 1.54	<= 3.09	<= 5.14	<= 8.23	<= 10.80	> 10.80	Total
0.0	0.74	1.41	1.95	1.11	0.07	0.00	5.28
22.5	0.55	1.49	1.69	0.79	0.02	0.00	4.54
45.0	0.84	2.98	2.65	1.03	0.03	0.00	7.53
67.5	0.94	2.43	2.13	0.55	0.02	0.03	6.10
90.0	0.87	2.03	1.76	0.37	0.02	0.00	5.05
112.5	1.00	2.06	1.46	0.29	0.01	0.00	4.83
135.0	1.35	2.29	2.19	0.66	0.03	0.00	6.51
157.5	1.35	3.45	2.60	0.76	0.04	0.00	8.21
180.0	1.13	2.57	4.16	2.05	0.09	0.00	9.99
202.5	1.03	1.54	2.76	1.97	0.15	0.00	7.45
225.0	1.46	2.41	3.08	1.73	0.13	0.01	8.82
247.5	1.85	3.57	1.65	0.47	0.03	0.00	7.58
270.0	0.63	0.81	0.62	0.40	0.07	0.03	2.56
292.5	0.34	0.56	0.97	1.32	0.29	0.05	3.53
315.0	0.42	1.08	1.94	1.60	0.23	0.01	5.28
337.5	0.44	1.56	2.05	1.28	0.16	0.01	5.50
Total	14.93	32.26	33.66	16.39	1.38	0.14	98.77
Calms							1.20
Missing							0.03
Total							100.00

As previously shown, the default AERMOD model is susceptible to overprediction for taller stacks located in elevated terrain. Figure A-2 presents the area surrounding the FutureFuel Chemical site with terrain contours overlaid to indicate the rolling nature of terrain and thus the potential for model overprediction in the areas to the north and southwest of the facility. Given the combination of steep terrain and low wind speed, the ADJ_U* option is very applicable to this analysis on a theoretical basis.

Figure A-2. Terrain Surrounding the FutureFuel Chemical Site



CRITERIA 3.2.2.e.iii - AVAILABILITY OF DATABASES

The test data bases and reporting for low wind speed observations and evaluation are available to assess model performance. The data bases applicable to this discussion and use of the u* option in AERMET and AERMOD are:

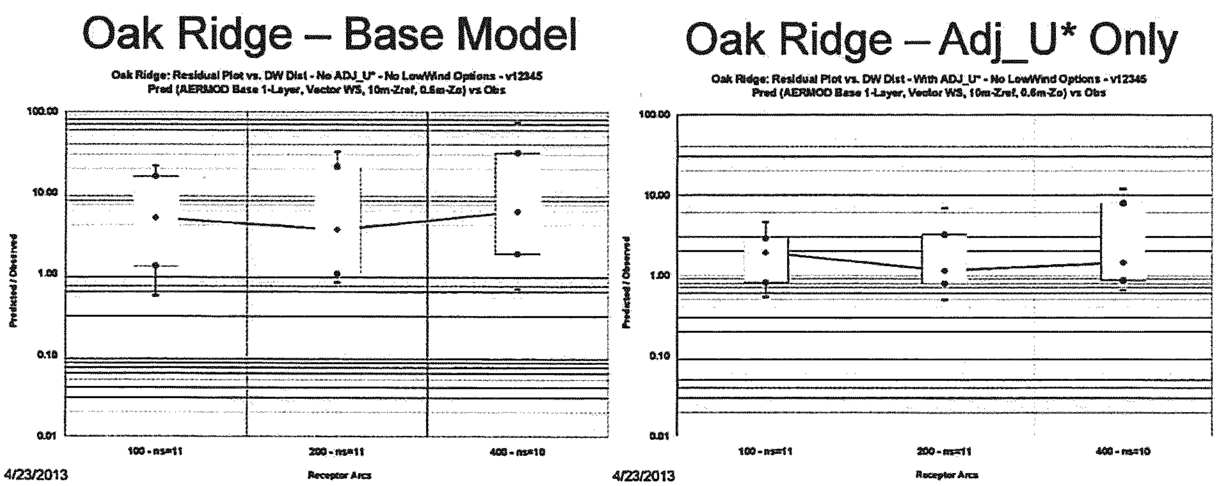
- Idaho Falls Study- Sagendorf JF, Dickson CR (1974) Diffusion under low wind speed, inversion conditions. NOAA Technical Memorandum ERL ARL-52, 89 pp.
- Prairie Grass Study - Barad ML (ed) (1958) Project Prairie Grass. A field program in diffusion. Geophysical research paper no. 59, vols I (300 pp) and II (221 pp). AFCRF-TR-58-235. Air Force Cambridge Research Center, Bedford, Massachusetts; under Model Evaluation Databases on U.S EPA's website - http://www.epa.gov/ttn/scram/dispersion_prefrec.htm
- Oak Ridge Study - NOAA Technical Memorandum ERL ARL-61, 1976. Diffusion under Low Wind Speed Conditions near Oak Ridge, Tennessee. Wilson, R. B., G. Start, C. Dickson, N. Ricks. Air Resources Laboratory, Idaho Falls, Idaho.

In addition, the AERMET source code and all input data required for implementing the ADJ_U* are publicly available on U.S. EPA's SCRAM website.

CRITERIA 3.2.2.e.iv - DEMONSTRATION OF NO BIASES TOWARDS UNDERESTIMATES

As demonstrated in a number of studies over the past 3-5 years, including the 2010 study by AECOM[20], the use of the u* adjustment in dispersion modeling has not shown any bias towards underestimating the ambient concentrations due to sources and emissions. A repeat use of the same Oak Ridge data set in 2013 by the U.S. EPA in their model performance evaluation demonstrates both the improved performance of AERMOD with u* option and no bias towards underestimation as shown in Figure A-3.

Figure A-3. Residual Plots Showing Improved Performance with u* and No Bias toward Underestimation



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[20] AERMOD Low Wind Speed Evaluation Study Results, AECOM prepared for the American Petroleum Institute, Washington, DC, March 22, 2010.

CRITERIA 3.2.2.e.v - A PROTOCOL HAS BEEN ESTABLISHED

This document serves as the modeling protocol being submitted to ADEQ by FutureFuel to clearly identify all of the data resources and modeling methodology proposed for use in the SO_2 Attainment analysis. There is discussion regarding the potential frequent occurrence of low winds due to the EPA-recommended use of the one-minute meteorological data available from the National Oceanic and Atmospheric Administration website.

The use of the LOWWIND options (e.g. LOWWIND3, which has been proposed for incorporation into the revised *Guideline*) was also considered to be appropriate for this modeling application. However, FutureFuel is proposing only ADJ_U* because it has been subject to extensive peer review and thus the likelihood of the approval of its use for this modeling exercise is greater.